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SUMMARY

Tests were made to determine bearing yield and ultimate strengths for several sizes of rolled and extruded 14S sections and of rolled 24S-T and 75S-T bar.[1] It was found that ratios of bearing to tensile properties previously proposed for aluminum-alloy sheet and plate appear equally applicable to rolled bar of 24S-T, 14S-W, and 14S-T in thicknesses up to 2 inches and to extruded 14S-W and 14S-T in thicknesses up to 1 inch. For rolled 75S-T bar in thicknesses up to 2 inches and for extruded 14S-W and 14S-T bar in the thickness range of 1 to 2 inches, lower ratios of bearing to tensile properties are proposed.

INTRODUCTION

A survey of the work done in the Aluminum Research Laboratories on the determination of bearing properties for use in the design of riveted, bolted, or pin-connected joints in the high-strength, wrought-aluminum alloys shows that a great many tests have been made on sheet and plate (references 1 to 5) but that little or no work has been done on forgings or rolled bar. The tests that have been made on extrusions, moreover, have been limited for the most part to alloy 75S-T with a few tests on sections of 24S-T (reference 1).

The need for some investigation of the bearing-strength characteristics of different forms of the same alloy was first indicated by the results obtained from tests of sheet and large extrusions of 24S-T. The bearing strengths for a $3\frac{3}{4}$-inch-thick extrusion, for example, were found to be considerably lower, in proportion to the tensile strength, than those for sheet material. The same general tendencies have since been observed for sheet and extrusions of 75S-T. The tests described in this report were undertaken to supplement these findings with observations on the behavior of 14S extrusions. Samples of rolled bar in 14S-T, 24S-T, and 75S-T have also been included.

The object of these tests was to determine bearing yield and ultimate strengths for several sizes of rolled and extruded high-strength, aluminum-alloy sections and to establish, as far as possible, typical

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[1]New temper designations for alloys listed are: 14S-T4 for 14S-W, 14S-T6 for 14S-T, 24S-T4 for 24S-T, 75S-T6 for 75S-T.

ratios of bearing to tensile properties for these types of product. Data of this kind are of interest mainly in the design of riveted, bolted, or pin-connected joints.

MATERIAL

Table I summarizes the mechanical properties obtained for the various test sections. The average tensile properties were in every case above the minimum specified (reference 6) and with a few exceptions (mainly 14S-W extruded bar) were in the range considered typical for these alloys. Although a number of comparisons may be made from the values shown in table I, the following are perhaps of most interest:

1. The extruded sections of both 14S-W and 14S-T angle and bar exhibited higher strengths and lower elongations than those observed for the corresponding rolled sections.

2. The strengths of the 14S-W and 14S-T extruded bar in the 2- by 2-inch size were higher than those obtained for the extruded 1- by 2-inch size, whereas the order of strengths with respect to size was just reversed in the case of the 14S-T rolled sections.

3. There was no significant difference in tensile properties for the two locations investigated in the bar sections, except in the case of the 75S-T. For the 2- by 2-inch size in the latter alloy the strengths obtained for specimen 1, located near the surface as shown in the sketch below table I, were considerably lower than those obtained for specimen 2, located about midway between the surface and the center. The strength values shown in table I for this section are the average of two tests at each location, whereas single tests at each location were made for all other samples.

PROCEDURE

Bearing tests were made in duplicate on $\frac{1}{4}$-inch-thick specimens from each sample, and loadings on a $\frac{1}{2}$-inch-diameter steel pin were used. The specimens machined from the angle sections were $2\frac{1}{4}$ inches wide; all those taken from the bar sections were 2 inches wide. The original length of all specimens was about 18 inches. After the completion of one test, the damaged end was sawed off about 1 inch below the center of the hole and the specimen was redrilled for another test. The sketches below table II indicate the location of the bearing specimens in the bar and angle cross sections.

Edge distances, measured from the center of the pin hole to the edge of the specimen in the direction of stressing, were limited in these tests to 1.5 and 2 times the pin diameter. These are the edge distances for which allowable bearing design values are commonly given (reference 7).

Figure 1 shows the arrangement used in making bearing tests in a 40,000-pound-capacity Amsler hydraulic testing machine. The hole elongations, from which values of bearing yield strength were determined, were measured by means of a filar micrometer microscope which could be read directly to 0.01 millimeter. The under side of the pin projecting from the specimen on the microscope side was flattened slightly to provide a reference mark for the determination of pin movement. A light scratch on the specimen under the pin provided a reference mark for specimen movement.

RESULTS AND DISCUSSION

Table II summarizes the results of the bearing tests. The yield strengths were selected from the bearing stress-hole elongation curves in figures 2 to 8 as the stresses corresponding to an offset from the straight-line portion of the curves equal to 2 percent of the pin diameter. Bearing failures occurred by shearing out the portion of the specimen above the pin or by a combination of shear and tensile fracture throughout the pin hole. In general, the behavior was similar to that observed for most of the other high-strength, wrought-aluminum alloys.

A comparison of the strength values given in tables I and II shows that the order of bearing strengths for the different sections and alloys was not always the same as observed for the tensile strengths. The bearing ultimate strengths for the rolled angle sections in both 14S-W and 14S-T, for example, were higher than those obtained for the extruded angles, yet the latter exhibited higher tensile strengths. There was no significant difference between the bearing values obtained for the 14S-T rolled and extruded bar, although there was a considerable difference between the tensile properties of these two types of section, particularly in the 2- by 2-inch size.

Table III gives the ratios of bearing to tensile properties obtained from the average results of these tests. It may be noted that the 14S-W angle and the 24S-T bar sections, having the lowest tensile strengths, developed some of the highest ratios of bearing to tensile properties. The lowest ratios, on the other hand, were observed for the 2- by 2-inch 14S extrusions and the 75S-T rolled bar, having the highest tensile strengths. The most significant observation to be made from the results of these tests, however, is that all the sections tested, with the exception of the 2- by 2-inch extruded bars of 14S-W and 14S-T and the rolled bars of 75S-T, may be placed in the same class as sheet and plate (reference 5) as far as ratios of bearing to tensile properties are concerned. Both the 1- by 2-inch and 2- by 2-inch sections of rolled

75S-T bar and the 2- by 2-inch extruded bars of 14S-W and 14S-T exhibited definitely lower ratios of bearing to tensile properties. The latter were of the same order of magnitude as previously observed for $\frac{1}{4}$-inch-thick extrusions of 75S-T (reference 3).

CONCLUSIONS

The following conclusions are based upon the results of bearing tests of several samples of rolled and extruded 14S sections and samples of rolled 24S-T and 75S-T bar:

1. The following ratios of bearing to tensile properties, previously proposed for aluminum-alloy sheet and plate, appear equally applicable to rolled bar of 24S-T, 14S-W, and 14S-T in thicknesses up to 2 inches and to extruded 14S-W and 14S-T in thicknesses up to 1 inch.

Ratios	Edge distances	
	1.5 × pin diameter	2 × pin diameter
$\frac{\text{Bearing ultimate}}{\text{Tensile ultimate}}$	1.5	1.9
$\frac{\text{Bearing yield}}{\text{Tensile yield}}$	1.4	1.6

2. For rolled 75S-T bar in thicknesses up to 2 inches and for extruded 14S-W and 14S-T bar in the thickness range of 1 to 2 inches, the following lower ratios of bearing to tensile properties are proposed:

Ratios	Edge distances	
	1.5 × pin diameter	2 × pin diameter
$\frac{\text{Bearing ultimate}}{\text{Tensile ultimate}}$	1.3	1.6
$\frac{\text{Bearing yield}}{\text{Tensile yield}}$	1.3	1.4

Aluminum Research Laboratories
Aluminum Company of America
New Kensington, Pa., January 20, 1947

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4. Moore, R. L., and Wescoat, C.: Bearing Strengths of 24S-T Aluminum Alloy Plate. NACA TN No. 981, 1945.

5. Moore, R. L.: Bearing Tests of 14S Sheet and Plate. NACA TN No. 1502, 1948.

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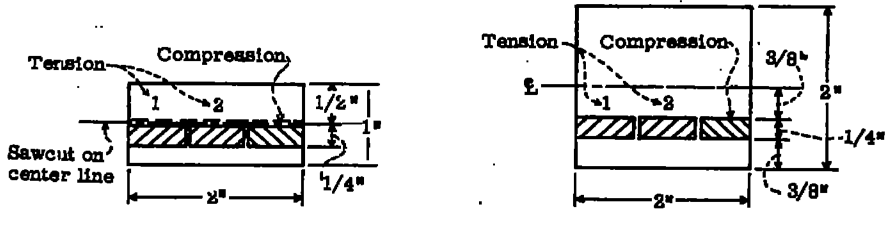
TABLE I

MECHANICAL PROPERTIES OF ALUMINUM-ALLOY ROLLED AND EXTRUDED SECTIONS USED IN BEARING TESTS

[All tensile specimens were standard sheet type for 2-in. gage length. Compression specimens from bar were $\frac{1}{4} \times \frac{5}{8} \times 2\frac{5}{8}$ in. Compression specimens from angle were of full cross section]

Alloy and temper	Section	Size (in.)	Sample	Speci-men	Tensile strength (psi)	Tensile yield strength (offset = 0.2 percent) (psi)	Elongation in 2 in. (percent)	Compressive yield strength (offset = 0.2 percent) (psi)
14S-W	Rolled angle	$3 \times 3 \times \frac{3}{8}$	75945	---	60,500	43,000	24.8	33,800
	Extruded angle	$3 \times 3 \times \frac{3}{8}$	75944	---	65,200	47,400	20.3	40,000
14S-T	Rolled angle	$3 \times 3 \times \frac{3}{8}$	75942	---	67,600	61,500	13.2	59,300
	Extruded angle	$3 \times 3 \times \frac{3}{8}$	75943	---	69,000	62,500	11.7	64,600
14S-W	Extruded bar	1 × 2	75603	1	66,200	49,300	17.6	40,800
				2	67,500	49,700	15.2	
				Av.	66,800	49,500	16.4	
14S-W	Extruded bar	2 × 2	75608	1	74,500	56,400	14.4	53,000
				2	76,200	58,800	14.4	
				Av.	75,400	57,600	14.4	
14S-T	Extruded bar	1 × 2	75604	1	69,200	63,400	11.2	63,100
				2	71,400	65,000	12.0	
				Av.	70,300	64,200	11.6	
14S-T	Rolled bar	1 × 2	74707	1	69,800	63,600	12.8	60,600
				2	68,800	62,900	11.2	
				Av.	69,300	63,200	12.0	
14S-T	Extruded bar	2 × 2	75609	1	75,900	67,300	10.4	68,800
				2	76,100	66,700	9.6	
				Av.	76,000	67,000	10.0	
14S-T	Rolled bar	2 × 2	74724	1	68,900	61,400	11.2	59,900
				2	68,500	60,800	12.0	
				Av.	68,700	61,100	11.6	
24S-T	Rolled bar	1 × 2	74711	1	68,000	48,600	20.0	42,100
				2	67,700	48,200	19.2	
				Av.	67,800	48,400	19.6	
24S-T	Rolled bar	2 × 2	74712	1	65,700	46,600	19.2	40,800
				2	65,100	46,400	18.4	
				Av.	65,400	46,500	18.8	
75S-T	Rolled bar	1 × 2	74713	1	87,400	79,900	12.8	79,300
				2	88,400	79,600	9.6	
				Av.	87,900	79,800	11.2	
75S-T	Rolled bar	2 × 2	73440	1	81,200	62,200	14.8	58,800
				2	91,300	75,700	8.0	
				Av.	86,300	69,000	11.4	



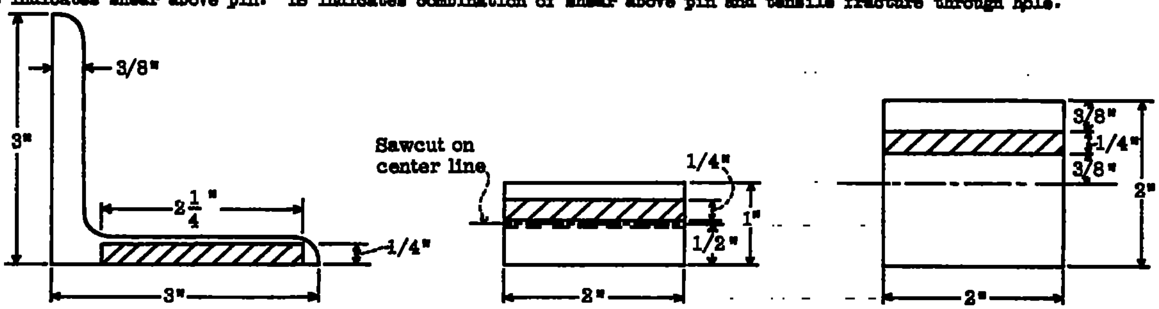
Location of tensile and compressive specimens in bar sections.

TABLE II

BEARING STRENGTHS OF ALUMINUM-ALLOY ROLLED AND EXTRUDED SECTIONS

Alloy and temper	Section	Size (in.)	Test	Bearing strengths (psi)					
				Edge distance = 1.5 × pin diameter			Edge distance = 2 × pin diameter		
				Ultimate	Yield (1)	Type of failure (2)	Ultimate	Yield	Type of failure
14S-W (73945)	Rolled angle	$3 \times 3 \times \frac{3}{8}$	1	98,400	63,800	S	124,100	72,500	S
			2	99,600	66,200	TS	123,800	71,400	S
			Av.	99,000	65,000		124,000	71,900	
14S-W (73944)	Extruded angle	$3 \times 3 \times \frac{3}{8}$	1	99,400	67,300	S	118,200	75,800	TS
			2	93,300	65,000	S	118,900	75,900	S
			Av.	96,400	66,200		118,600	75,900	
14S-T (73942)	Rolled angle	$3 \times 3 \times \frac{3}{8}$	1	104,900	87,100	TS	132,100	94,000	TS
			2	104,400	86,500	TS	130,700	94,100	TS
			Av.	104,700	86,800		131,400	94,100	
14S-T (73943)	Extruded angle	$3 \times 3 \times \frac{3}{8}$	1	104,300	87,100	S	128,900	93,500	TS
			2	100,300	83,800	TS	125,500	96,000	TS
			Av.	102,300	85,500		127,200	94,800	
14S-W (75603)	Extruded bar	1 × 2	1	99,000	66,000	S	120,100	76,300	TS
			2	95,400	65,000	S	124,500	78,800	TS
			Av.	97,200	65,500		122,300	77,500	
14S-W (75608)	Extruded bar	2 × 2	1	100,500	71,000	TS	124,000	81,000	TS
			2	99,300	68,000	TS	124,400	82,500	S
			Av.	99,900	69,500		124,200	81,800	
14S-T (75604)	Extruded bar	1 × 2	1	102,000	87,900	TS	131,700	99,200	TS
			2	102,000	84,200	TS	129,400	94,400	TS
			Av.	102,000	86,100		130,600	96,800	
14S-T (74707)	Rolled bar	1 × 2	1	101,300	87,700	TS	130,200	97,900	TS
			2	104,300	87,500	TS	128,700	97,200	TS
			Av.	102,800	87,600		129,500	97,600	
14S-T (75609)	Extruded bar	2 × 2	1	100,400	84,800	TS	126,300	96,900	TS
			2	102,000	84,800	TS	125,500	97,000	TS
			Av.	101,200	84,800		125,900	97,000	
14S-T (74724)	Rolled bar	2 × 2	1	99,400	86,500	TS	123,300	97,000	TS
			2	99,400	85,200	TS	125,000	96,000	TS
			Av.	99,400	85,900		124,200	96,500	
24S-T (74711)	Rolled bar	1 × 2	1	98,600	68,500	TS	122,800	82,700	S
			2	98,300	69,000	TS	123,200	84,200	TS
			Av.	98,500	68,800		123,000	83,500	
24S-T (74712)	Rolled bar	2 × 2	1	98,600	70,200	TS	122,600	79,500	TS
			2	98,200	70,000	TS	124,200	79,000	TS
			Av.	98,400	70,100		123,400	79,300	
75S-T (74713)	Rolled bar	1 × 2	1	113,200	105,400	TS	155,700	115,000	TS
			2	117,900	106,500	TS	148,200	117,100	TS
			Av.	115,500	105,900		151,900	116,100	
75S-T (73440)	Rolled bar	2 × 2	1	108,200	89,000	TS	137,600	101,500	TS
			2	110,900	88,500	TS	143,200	105,300	S
			Av.	109,500	88,800		140,400	103,400	

1Yield strength corresponds to offset of 2 percent of pin diameter on bearing stress-hole elongation curves.
2S indicates shear above pin. TS indicates combination of shear above pin and tensile fracture through hole.



Location of bearing specimens. All tests made on $\frac{1}{2}$-inch-diameter steel pin.

TABLE III

RATIOS OF AVERAGE BEARING TO TENSILE STRENGTHS

[BS, bearing ultimate strength; TS, tensile ultimate strength; BYS, bearing yield strength; TYS, tensile yield strength]

Alloy and temper	Section	Size (in.)	Ratios for edge distances of -			
			1.5 x pin diameter		2 x pin diameter	
			BS/TS	BYS/TYS	BS/TS	BYS/TYS
14S-W	Rolled angle	$3 \times 3 \times \frac{3}{8}$	1.64	1.51	2.05	1.67
14S-W	Extruded angle	$3 \times 3 \times \frac{3}{8}$	1.48	1.40	1.82	1.60
14S-T	Rolled angle	$3 \times 3 \times \frac{3}{8}$	1.54	1.41	1.94	1.53
14S-T	Extruded angle	$3 \times 3 \times \frac{3}{8}$	1.48	1.37	1.85	1.52
14S-W	Extruded bar	1 x 2	1.46	1.32	1.83	1.56
14S-W	Extruded bar	2 x 2	1.33	1.21	1.65	1.42
14S-T	Extruded bar	1 x 2	1.45	1.34	1.86	1.51
14S-T	Rolled bar	1 x 2	1.48	1.39	1.87	1.55
14S-T	Extruded bar	2 x 2	1.33	1.27	1.66	1.45
14S-T	Rolled bar	2 x 2	1.45	1.41	1.81	1.58
24S-T	Rolled bar	1 x 2	1.45	1.42	1.81	1.73
24S-T	Rolled bar	2 x 2	1.51	1.51	1.89	1.71
75S-T	Rolled bar	1 x 2	1.32	1.33	1.73	1.46
75S-T	Rolled bar	2 x 2	1.27	1.29	1.63	1.50

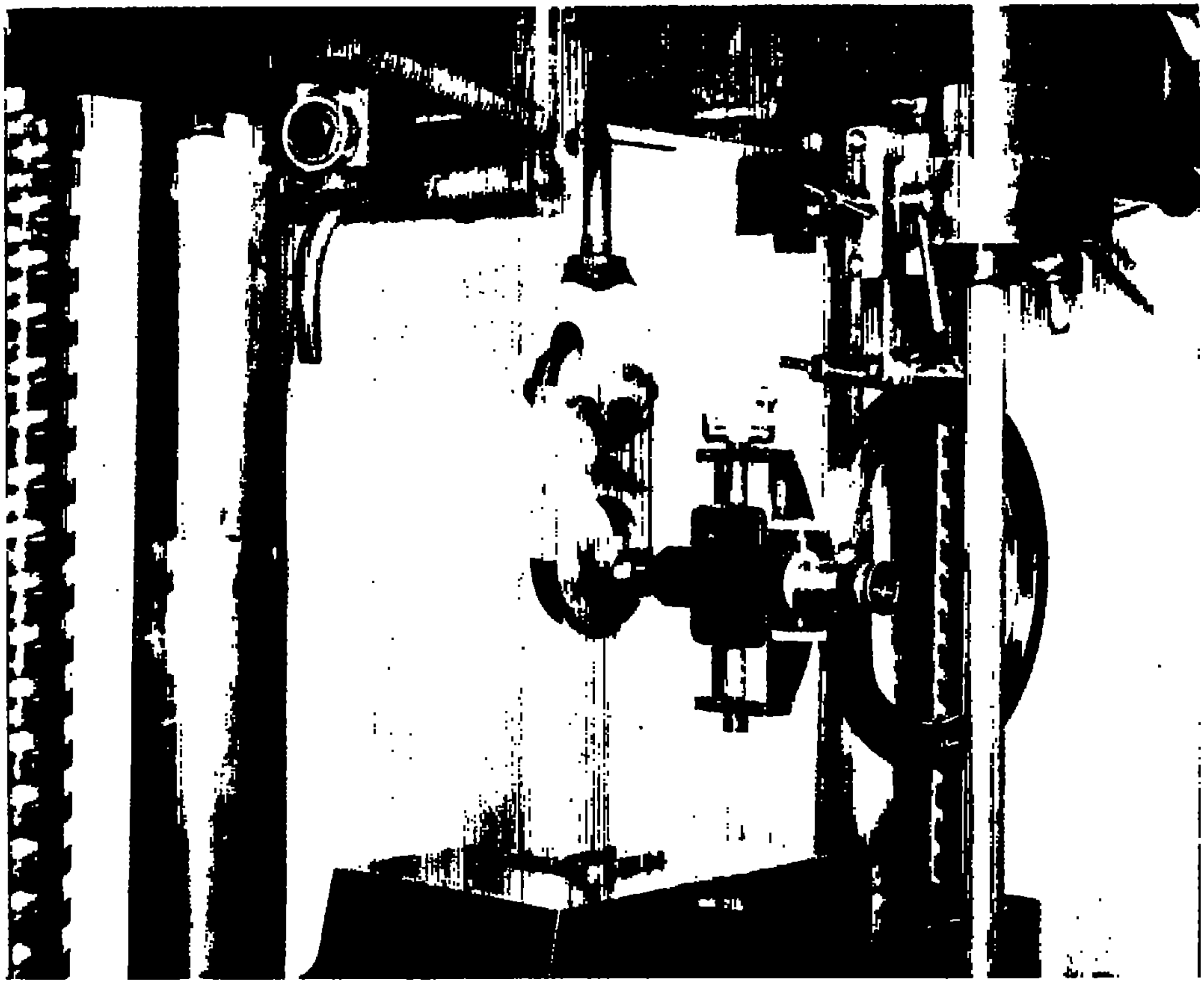


Figure 1.- Arrangement for bearing tests. Microscope used for measurement of hole elongations.

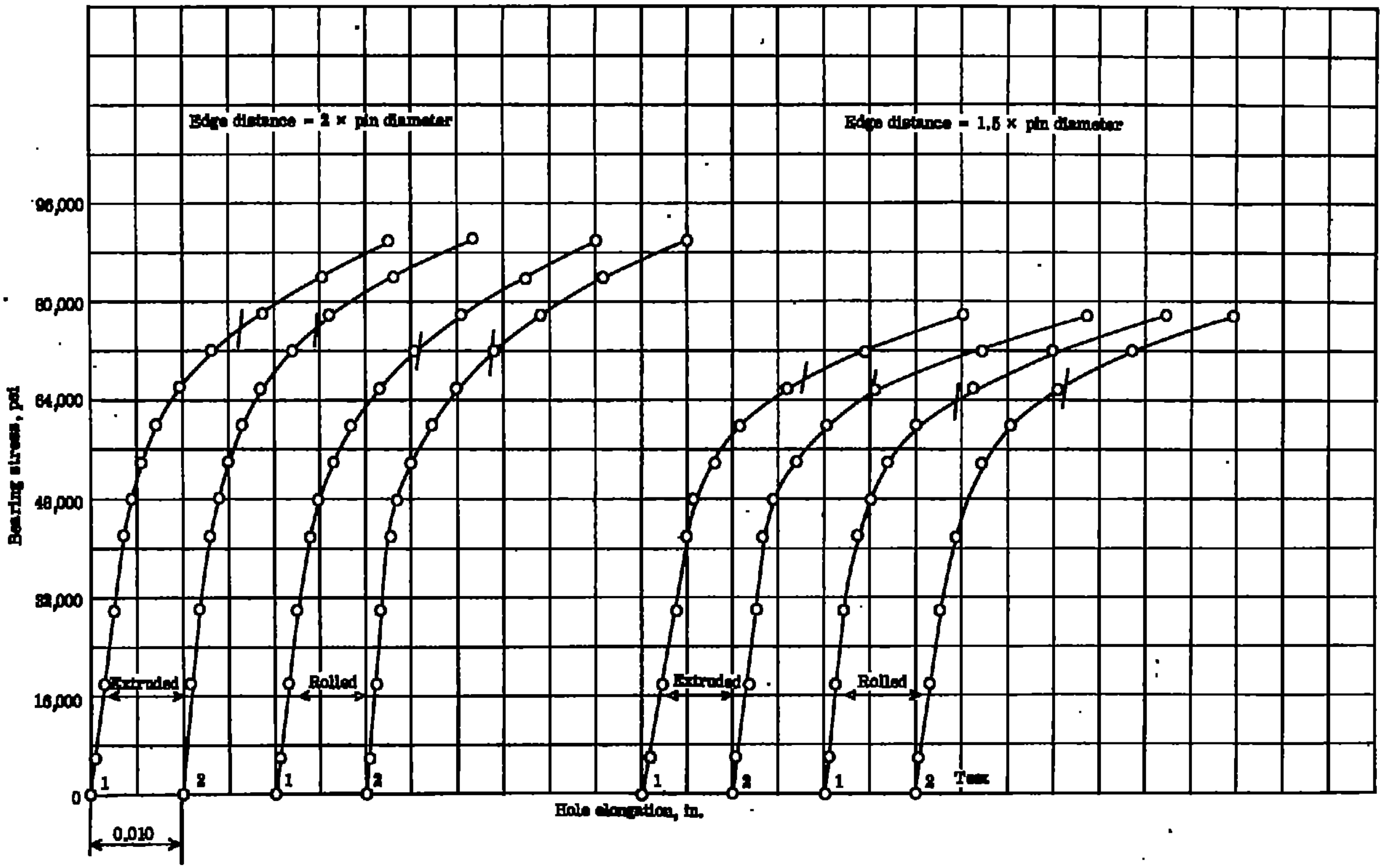


Figure 2.- Bearing stress-hole elongation curves for 3- by 3- by $\frac{3}{8}$-inch 14S-W angle (samples 75944 and 75945). Specimen thickness, 0.250 inch; specimen width, $2\frac{1}{4}$ inches; pin diameter, 0.500 inch; bearing-yield offset, 0.02 × pin diameter.

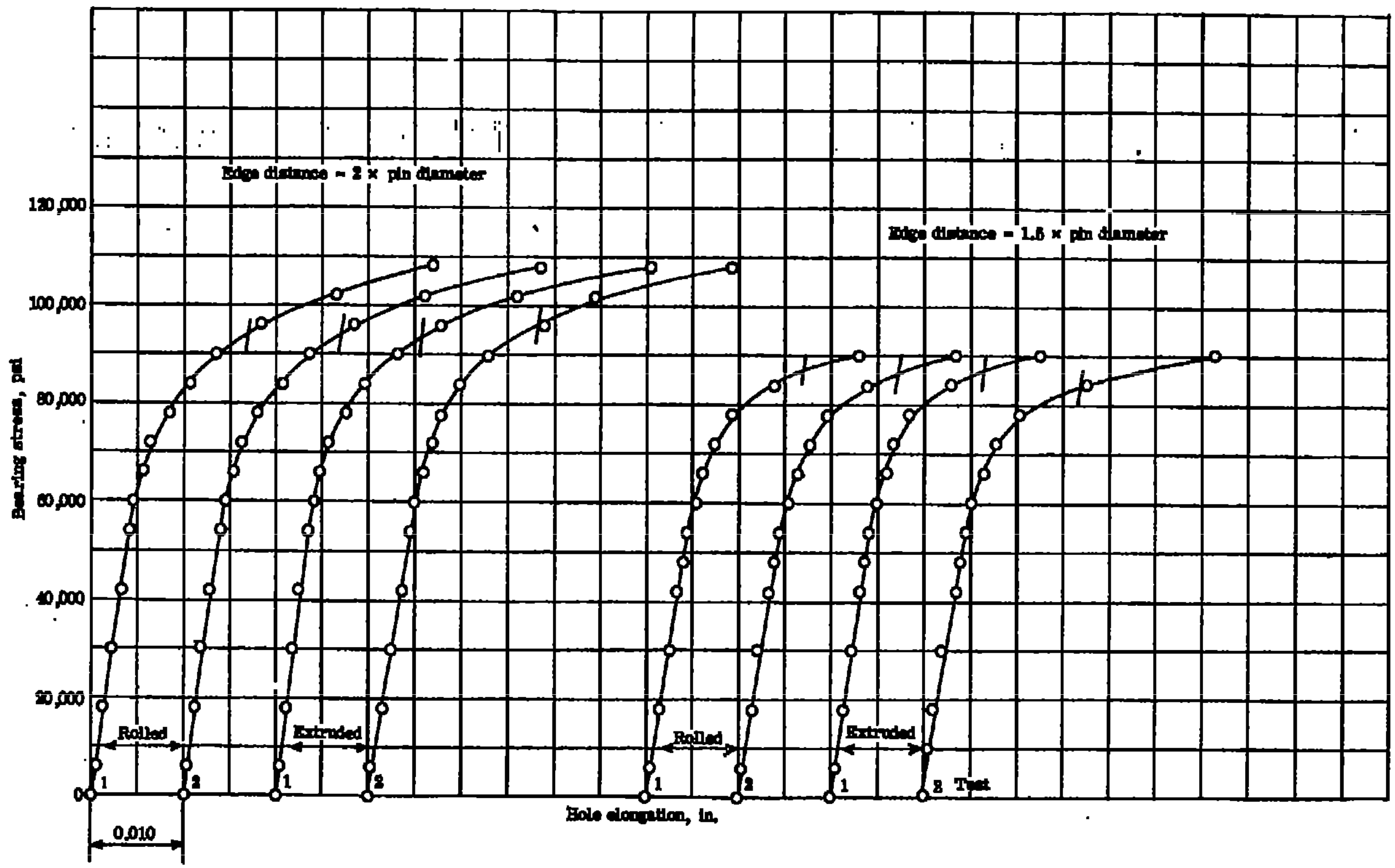


Figure 3.- Bearing stress-hole elongation curves for 3- by 3- by $\frac{3}{8}$-inch 14S-T angle (samples 75942 and 75943). Specimen thickness, 0.250 inch; specimen width, $2\frac{1}{4}$ inches; pin diameter, 0.500 inch; bearing-yield offset, 0.02 × pin diameter.

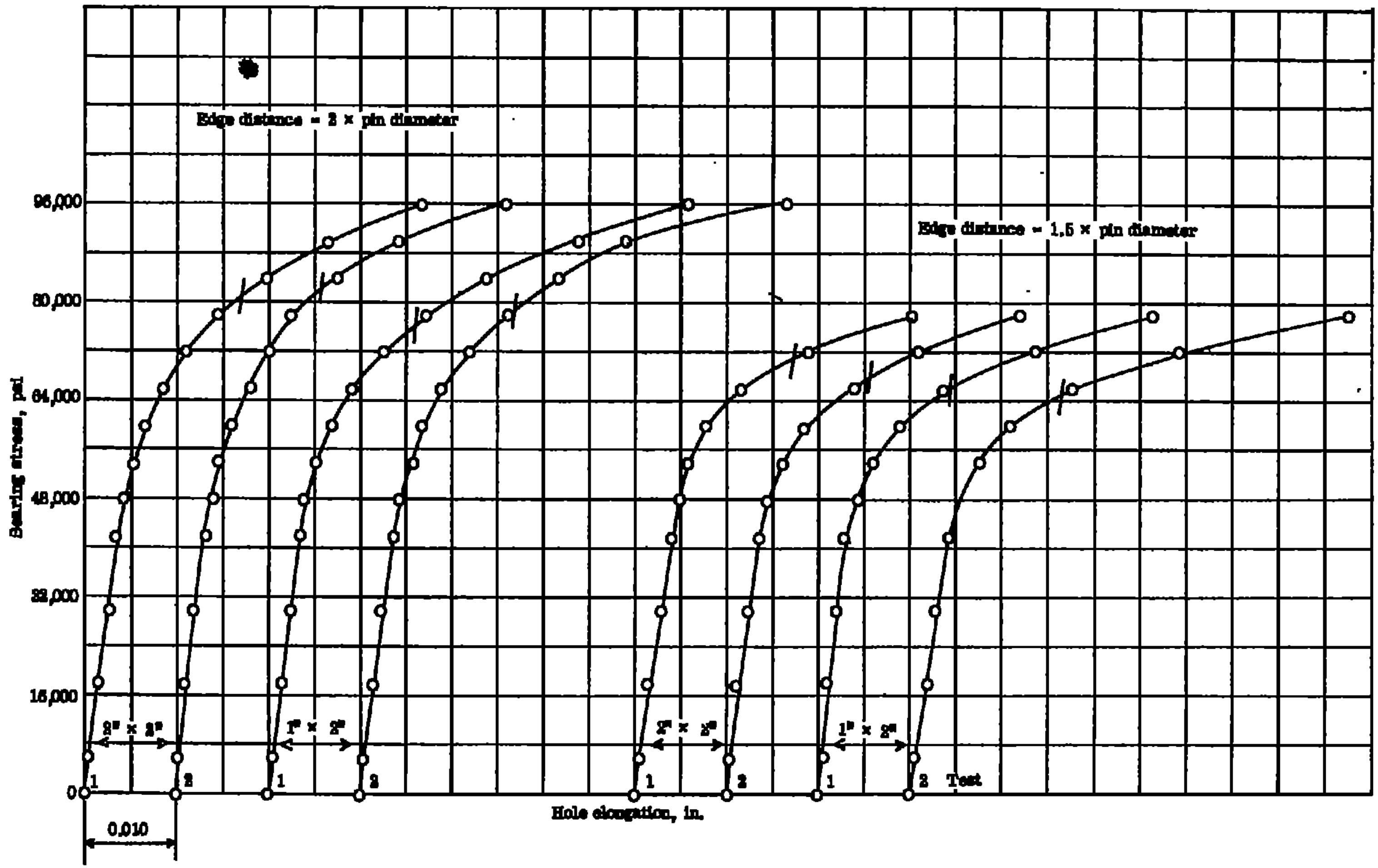


Figure 4.- Bearing stress-hole elongation curves for 14S-W extruded bar (samples 75603 and 75608). Specimen thickness, 0.250 inch; specimen width, 2 inches; pin diameter, 0.500 inch; bearing-yield offset, 0.02 × pin diameter.

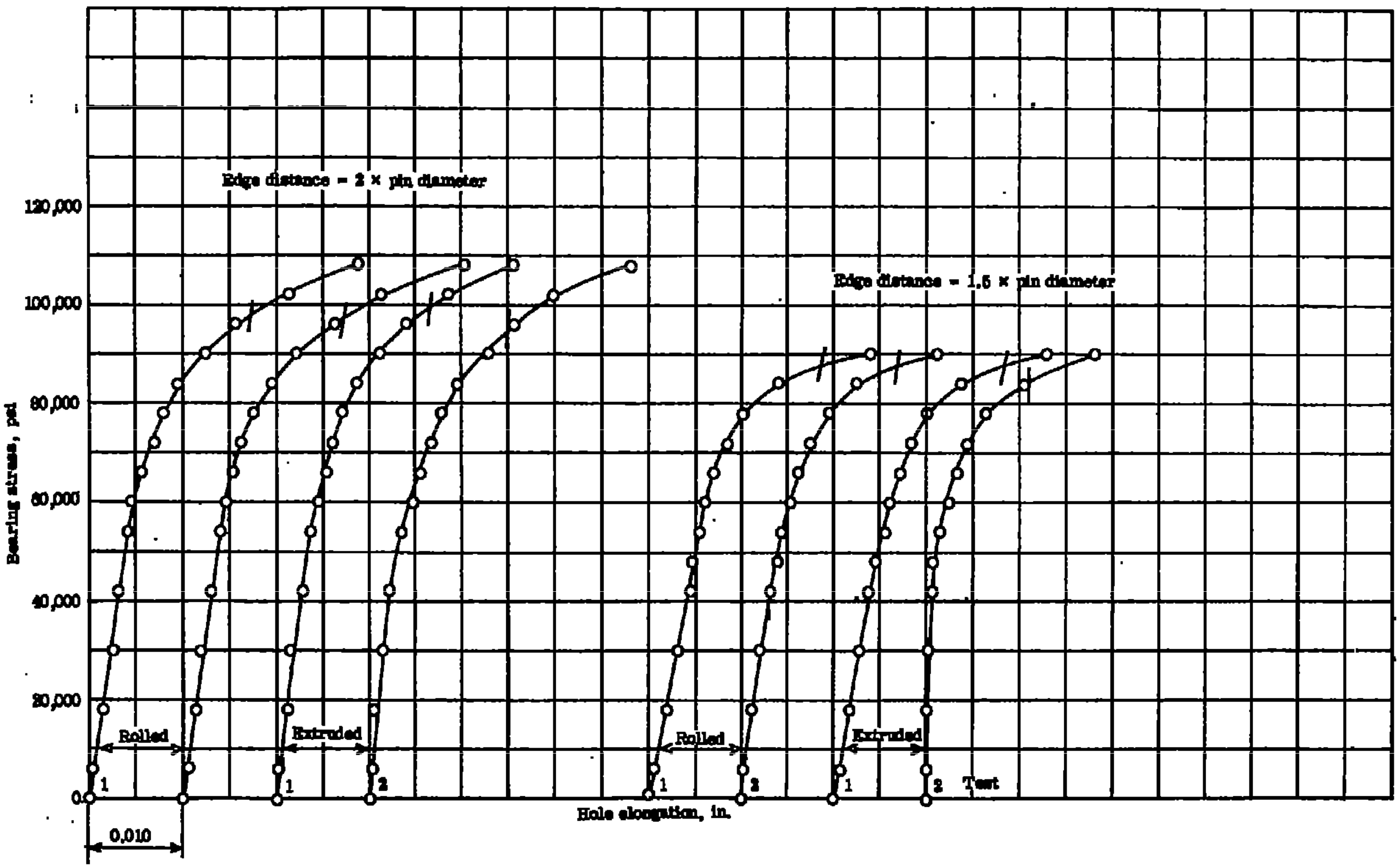


Figure 5.- Bearing stress-hole elongation curves for 1- by 2-inch 14S-T bar (samples 74707 and 75604). Specimen thickness, 0.250 inch; specimen width, 2 inches; pin diameter, 0.500 inch; bearing-yield offset, 0.02 × pin diameter.

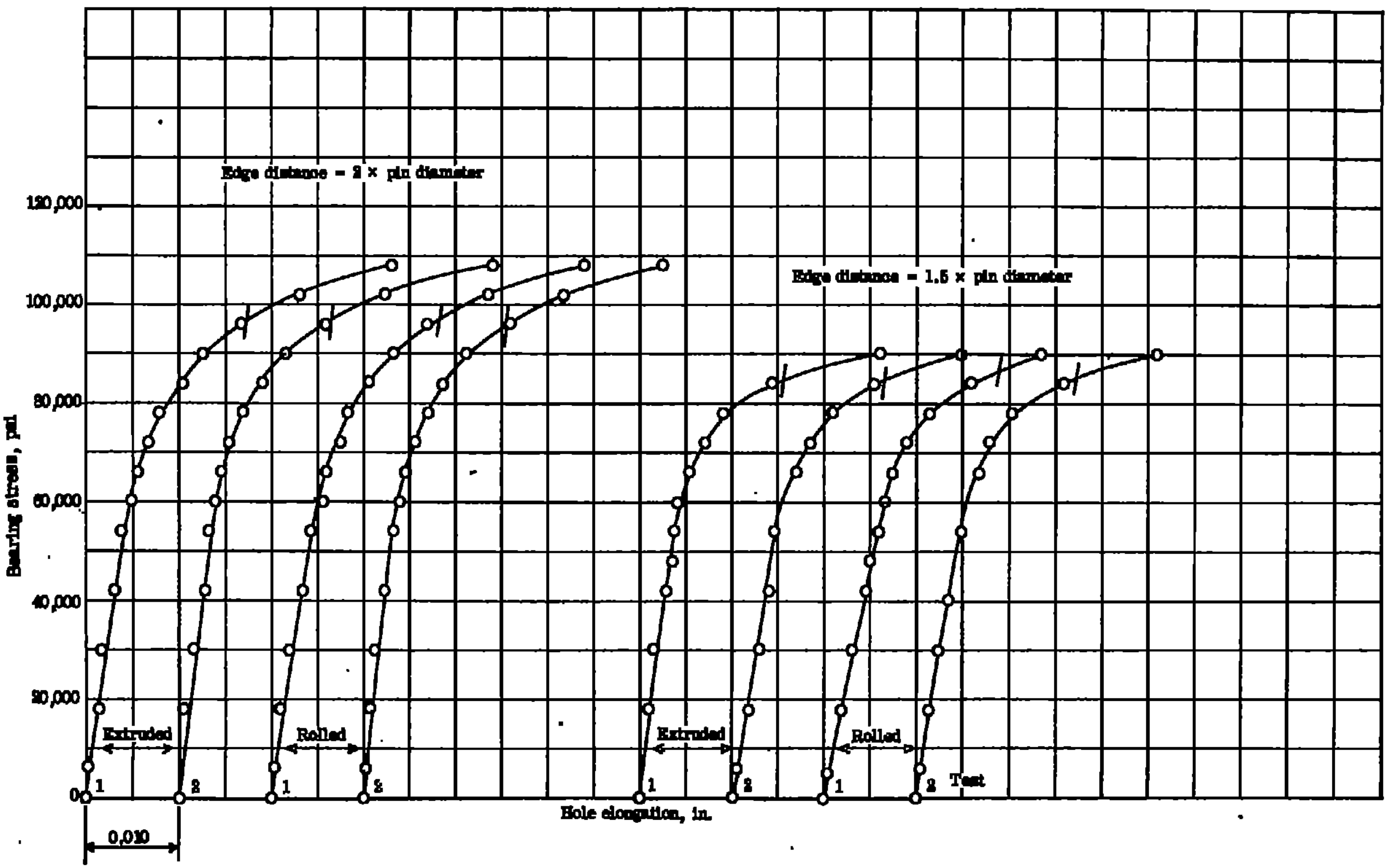


Figure 6.- Bearing stress-hole elongation curves for 2- by 2-inch 14S-T bar (samples 74724 and 75609). Specimen thickness, 0.250 inch; specimen width, 2 inches; pin diameter, 0.500 inch; bearing-yield offset, 0.02 × pin diameter.

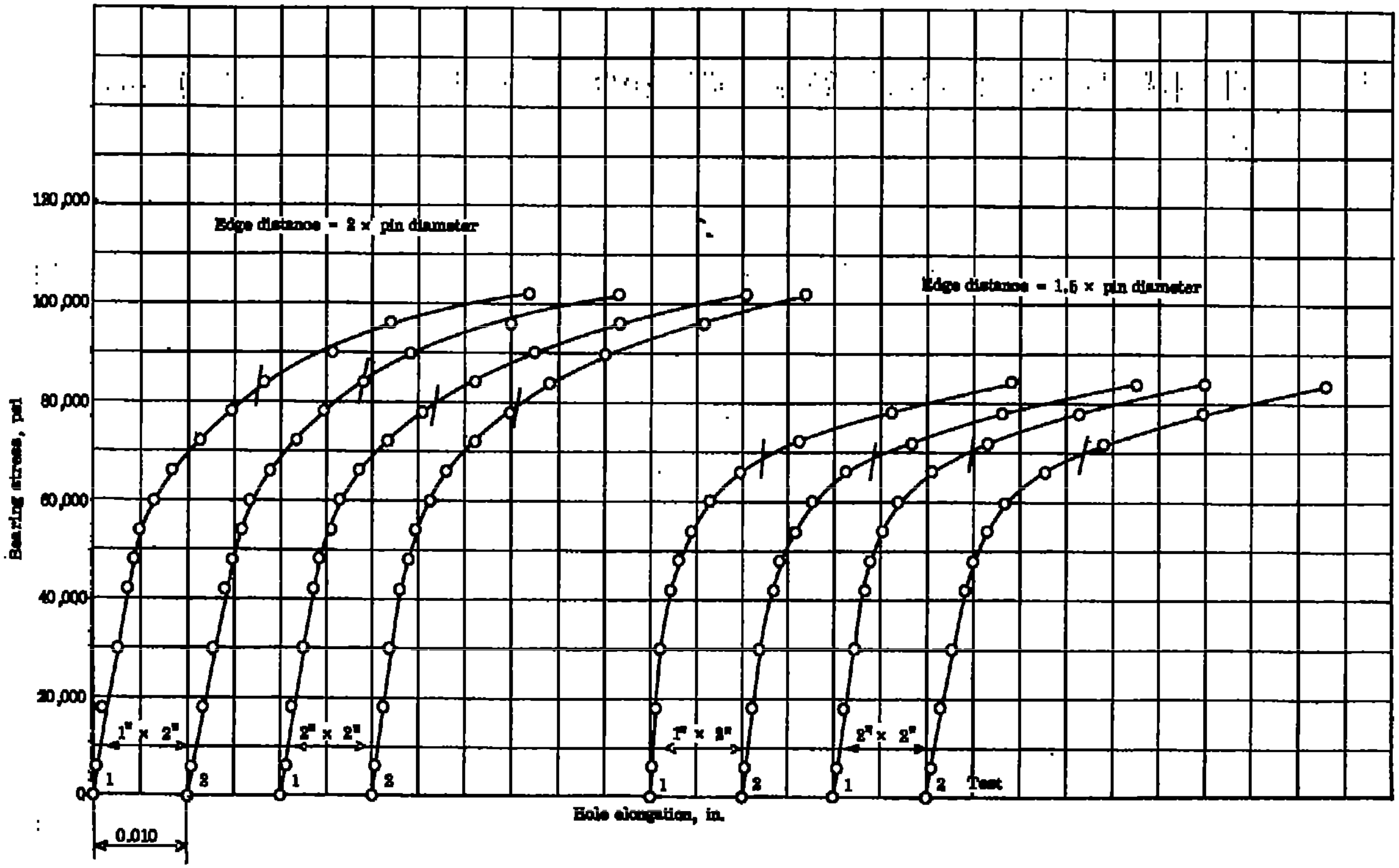


Figure 7.- Bearing stress-hole elongation curves for 24S-T rolled bar (samples 74711 and 74712). Specimen thickness, 0.250 inch; specimen width, 2 inches; pin diameter, 0.500 inch; bearing-yield offset, 0.02 × pin diameter.

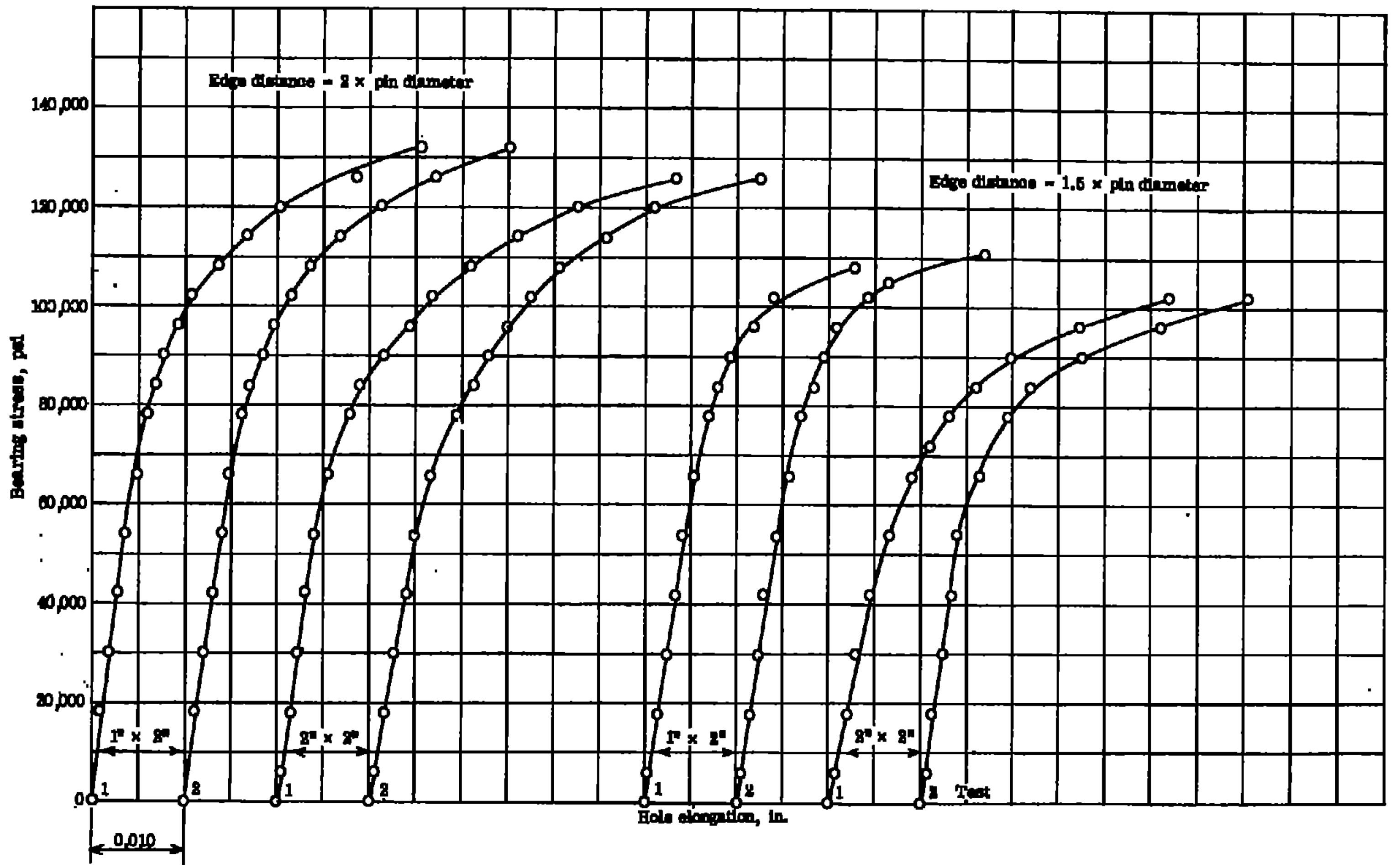


Figure 8.- Bearing stress-hole elongation curves for 75S-T rolled bar (samples 73440 and 74713). Specimen thickness, 0.250 inch; specimen width, 2 inches; pin diameter, 0.500 inch; bearing-yield offset, 0.02 × pin diameter.